

# Atmospheric Forcing of Ocean Convection in the Labrador Sea

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## LONG-TERM GOAL

My long-term goal is to improve our ability to model and predict dynamic and thermodynamic ocean processes in high-latitude regions. Specifically, I seek to understand and predict how atmospheric forcing such as surface momentum, heat and salinity fluxes affects the ocean.

## OBJECTIVES

The ultimate objective of this study is to understand the relation between atmospheric forcing and deep convection in high-latitude seas, in particular, the Labrador Sea. The atmosphere provides the crucial input into the upper ocean, which results in destabilization and convection in the ocean. A necessary component of this objective is to verify and improve the parameterizations which numerical models use to specify surface fluxes over high-latitude marine regions. Another objective is to enhance our understanding of how these surface fluxes are related to upper-level and large scale atmospheric features. Finally, I seek to quantify the various feedbacks that occur between the ocean and atmosphere in the Labrador Sea and other high-latitude oceans.

## APPROACH

My approach was to directly measure *in situ* surface and upper-level meteorological parameters during the 1997 and 1998 Labrador Sea Deep Convection Experiments. During the 1997 cruise of the *R/V Knorr* I performed the radiation and upper-air measurements; groups from the Bedford Institute of Technology (Fred Dobson), University of Kiel (Karl Bumke) and the NOAA Environmental Laboratory (Ola Persson) also provided equipment and personnel to measure turbulent fluxes directly. These measurements were compared with numerical model and aircraft results, in collaboration with Ian Renfrew at the British Antarctic Survey and G.W. Kent Moore at the University of Toronto. I also used data collected during the 1998 Knorr cruise to estimate the total surface heat and momentum budgets. The last year's efforts were primarily devoted to a comparison of the atmospheric forcing parameters (heat and momentum) of various numerical models with conditions measured *in situ* on the *R/V Knorr* during the 1997 cruise.

A new (unfunded on my part) effort involves a comparison of data from Lagrangian floats deployed by Eric D'Asaro and colleagues during the 1997 cruise with results from a non-hydrostatic Large Eddy Simulation (LES) model. The LES model was adapted for the ocean by the Oceanic Boundary Planetary Boundary Layer (OPBL) Laboratory at the Naval Postgraduate School (NPS). A paper

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undergoing final revision by Ramsey Harcourt, Eric D'Asaro, Roland Garwood, Jr., and Elizabeth Steffen describes (among other things) an enhanced temperature variance in the near-surface ocean observed in the Lagrangian drifters but not simulated by the LES model. We hypothesize that this variance is a result of small horizontal density gradients. My student, LTC Denise Kruse, USN, as part of her M.S. thesis requirement at NPS, will incorporate a density gradient into the LES model in order to examine the hypothesis. This will be done in collaboration with Harcourt and Garwood of the OPBL group at NPS.

## **WORK COMPLETED**

I improved a web page describing my measurements and results for the Labrador Sea Deep Convection Experiment (<http://www.weather.nps.navy.mil/~guestps/labsea>).

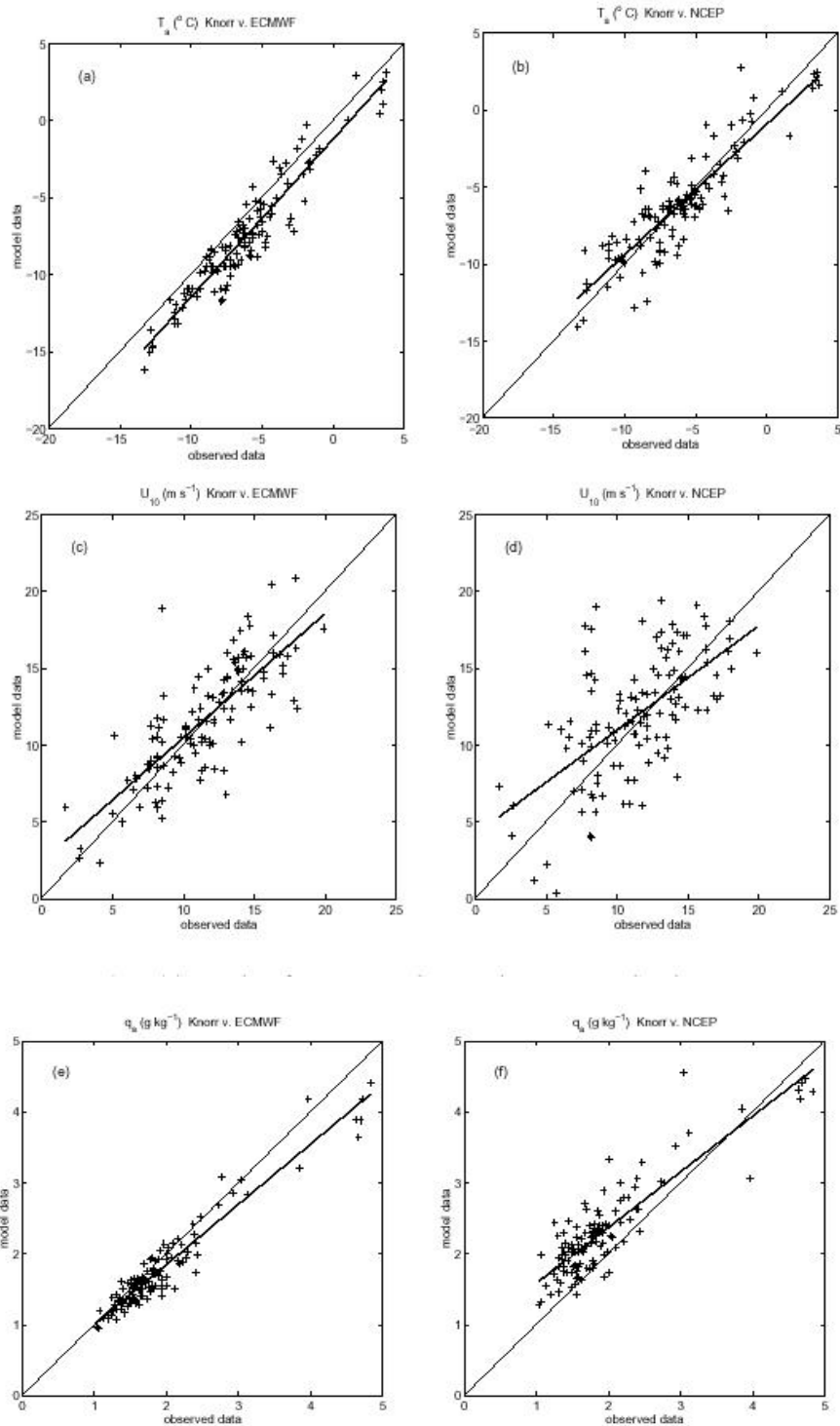
A major accomplishment in the last year was the completion of a study comparing surface layer standard meteorological parameters and surface heat and momentum fluxes with results from the European Centre for Medium Range Weather Forecasting (ECMWF) and the National Center for Environmental Prediction (NCEP) reanalysis products (Renfrew et al., 2000). Another accomplishment was a study of the mesoscale forecasting provided during the 1997 cruise (Renfrew et al., 1999). I also contributed to an overview of the Labrador Sea Deep Convection Experiment (The Lab Sea Group, 1998). I used a small amount of the ONR support to work on topics related to the Surface Heat Budget of the Arctic Project (SHEBA), which resulted in several conference presentations (refs. listed below).

## **RESULTS**

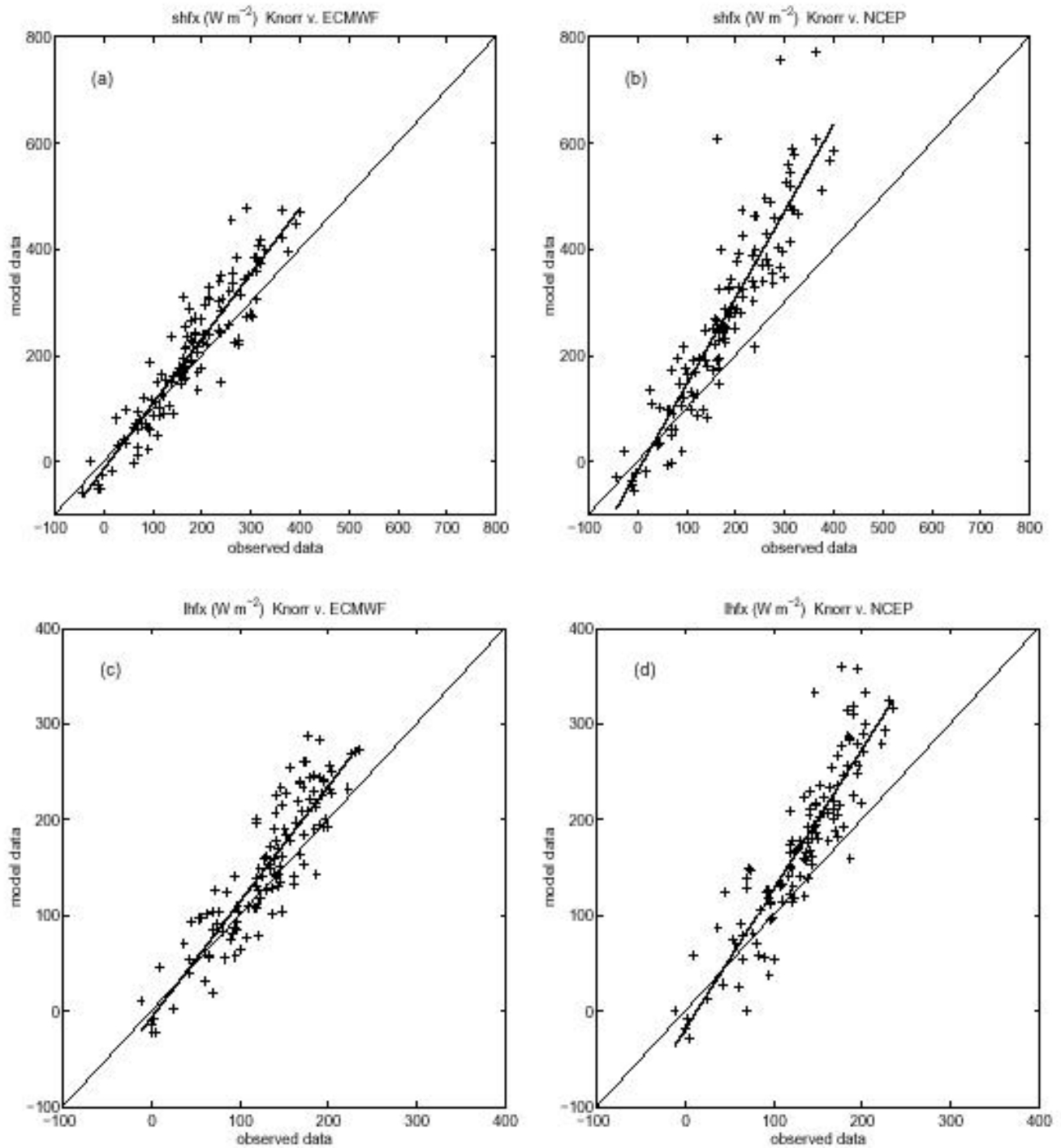
See the web page for a description of the *in situ* observational results.

Our comparison of numerical forecast models showed that both the ECMWF and the NCEP models did a reasonably good job of forecasting surface winds, temperature and humidity during the winter of 1997 in the Labrador Sea (Figure 1). The ECMWF also predicted sensible and latent heat flux fairly well, with a slight overprediction of about 15% (Figure 2). However the NCEP model reanalysis seriously overpredicted the heat fluxes, by 50% and 30% for sensible and latent heat fluxes, respectively (Figure 2). The cause of the NCEP overprediction was a bulk surface layer algorithm that was not appropriate for the large air-sea temperature differences and high wind speeds that occurred. The current NCEP operational bulk surface layer algorithm has been improved and is more accurate.

The paper on forecast support (Renfrew et al., 1999) showed the importance of having a specially tailored forecast model in regions with strong mesoscale features such as were present during the 1997 Labrador Sea Deep Convection Experiment. The Navy's Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS) was the primary forecast tool that provided the forecasts. It proved to be a valuable tool for planning aircraft flights and ship operations during the field program.



**1. Scatterplots of Knorr observations vs. ECMWF model (left panels) and Knorr measurements vs. NCEP model basic meteorological surface data. Top panels compare 2-m air temperatures, middle panels compare 10-m wind speeds and bottom panels compare specific humidity. The linear regression (darker line) assumes the observed data is independent.**



**2. Scatterplots of Knorr observations vs. ECMWF model (left panels) and Knorr measurements vs. NCEP model surface turbulent heat flux data. Top panels compare sensible heat fluxes and bottom panels compare latent heat fluxes. The linear regression (darker line) assumes the observed data is independent.**

## **IMPACT/APPLICATIONS**

Our results revealed some serious problems with the prediction of surface heat flux over the ocean by some operational models. These numerical models typically provide all the information we have concerning atmospheric forcing of the ocean. Therefore a bias in these models means that incorrect heat fluxes are being specified throughout the World Ocean. These results should help correct this problem.

## **TRANSITIONS**

I have provided the surface and upper-air data sets to anyone who asked; there were over 14 requests. The problems with the NCEP model have been brought to the attention of the developers of this model and we anticipate improvements in their bulk surface heat flux algorithm

## **RELATED PROJECTS**

I participated in the Surface Heat Budget of the Arctic (SHEBA) experiment as a member of the atmospheric surface flux group. I completed a study of surface longwave radiation conditions in the Weddell Sea. I teach a course on Polar Meteorology to US Navy officers every year and plan to write the first textbook on this topic. I am currently working on a web module on the topic of Polar Meteorology that will serve as a stand-alone educational resource and as a compliment to the hardcopy textbook. The web module will be continuously updated with the latest research results and links to other web sources.

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See publications.

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